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Ares I-X Vibroacoustic Environments

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Version	Description of Revision	Author	Effective Date
	Initial Release	Dr. Curtis E. Larsen, Technical Fellow for Loads and Dynamics, and Mr. Daniel Kaufman, NESC Discipline Deputy for Loads and Dynamics	6-26-08

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Volume I: Technical Report

1.0 Authorization and Notification

Mr. R. Marshall Smith, of the Ares I-X Systems Engineering and Integration (SE&I) Project Office at NASA Langley Research Center, requested the consultation of NESC to resolve technical issues in continuing discussion at the Ares I-X Vibroacoustic Environments Panel. An NESC out-of-board activity was approved February 20, 2008 and Dr. Curtis E. Larsen, NASA Technical Fellow for Loads and Dynamics, was chosen to lead this consultation. The environments issues needed to have timely and technically sound resolution for the Ares I-X vibroacoustics environments team to adequately support Ares I-X vehicle development.

The key stakeholder for this consultation is Mr. R. Marshall Smith.

2.0 Signature Page

Assessment Team Members

Team signature on file 8-12-08

Dr. Curtis E. Larsen	Date	Dr. David M. Schuster	Date
Mr. Daniel S. Kaufman	Date		

3.0 Team List

Name	Discipline	Organization/Location
Core Team		
Curtis Larsen	Technical Fellow, Loads & Dynamics	JSC
David Schuster	Technical Fellow, Aerosciences	LaRC
Daniel Kaufman	NESC Discipline Deputy for Loads & Dynamics	GSFC
Consultants		
Mark Silverman	Vibroacoustics	The Aerospace Corporation
Mark Mueller	Propulsion	The Aerospace Corporation
Support		
Chris Johansen	MTSO Program Analyst	LaRC
Erin Moran	Technical Writer	LaRC, ATK

4.0 Executive Summary

This paper provides a summary of the NASA Engineering and Safety Center (NESC) team recommendations and observations following participation with the Ares I-X Vibroacoustic (VA) Environments Panel in meetings at the Kennedy Space Center (KSC) and the Marshall Space Flight Center (MSFC) in March and April 2008, respectively. Overall, the meetings went well and progress was made on both the definition of the acoustic environments and the component vibration assessments. Significant differences of opinion among panel participants were resolved and a consensus was reached. A few remaining minor concerns were noted in the panel minutes.

The following NESC team recommendations are made in regard to general use of "heritage" hardware by Ares I-X:

- Ares I-X should verify environmental (VA) qualification heritage for all actual flight hardware. This should include verification of whether the components were qualified power ON or OFF during tests. If the heritage qualification levels (durations and power status) are inadequate or non-existent, then the hardware should be re-qualified.
    - Re-qualify the RoCS hardware since it was not previously qualified to be operational during the high vibration liftoff and ascent regime.
- Ares I-X should expand the heritage evaluation beyond the environmental (VA) aspect (i.e., verify item design requirements, purpose, functionality, performance, reliability, etc.).
- Ares I-X should perform its own VA acceptance testing for all actual flight hardware (except pyro valves for which lot testing is typical).
- Ares I-X should create a Requirements Verification Matrix and keep it up to date for the hardware.
- Ares I-X should implement configuration management and traceability for military off-the-shelf items.
    - This should include keeping tracking records of heritage data (past qualification and acceptance records) and actual testing (qualification and acceptance).

Recommended logic flows for considering heritage hardware VA qualification and acceptance are also provided.

5.0 Consultation Overview

During the Ares I-X VA panel meetings held March, 11-12 and April 1-3, 2008, the team members discussed issues related to the acoustic environments and element vibration assessments for which the panel previously could not reach a consensus. Discussions centered on whether it was inherently conservative to use a P95/50 +3 decibels (dB) expected flight environment, as proposed by the panel chairman, rather than the P97.5/50 dB criteria that is normally used by engineers at MSFC. It was ultimately agreed that the two approaches were equivalent based on a comparative analysis provided by Mark Silverman (The Aerospace Corporation).

Liftoff acoustic environment estimates provided by Jacobs Engineering (Jacobs) were compared with those made independently by NESC and The Aerospace Corporation (Aerospace). They were also compared with the previously released environments in the Ares I-X VA databook. In most zones along the vehicle's height the Jacobs and Aerospace environments generally matched. There was agreement in the final enveloping environment for the Ares I-X because the Jacobs and Aerospace assessments were each derived from various different launch vehicles of different types of pads. The panel agreed on an acoustic spectra that was a few decibels lower than the environments released in December, 2007.

Following the discussions, a formal vote was taken and representatives from each Integrated Product Team (IPT) accepted the new acoustic levels. The Jacobs/MSFC Engineering team requested their comments be noted with regard to the high frequency end of a few spectra where they would have enveloped the data at a higher level. However, this was not an obstacle to their acceptance of the spectra since the frequencies in question were beyond those used in the subsequent vibration analyses (acoustics are provided up to 10,000 Hz, but hardware vibration assessment is only performed to 2000 Hz).

A concern for the NESC team and panel members was acoustic spectrum reductions of 10-20 dB that was proposed by Mr. Roger Lenard with apparent inadequate justification. The NESC team and MSFC panel members assessed that his analysis was flawed based on their collective experience in using the methods documented in the NASA Special Publication (SP) "Acoustic Loads Generated by the Propulsion System" (NASA SP-8072). Mr. Lenard could not satisfactorily defend his results to the panel and his predictions were disregarded in determining the final liftoff acoustic environments for the databook.

Based on the status discussions presented for the on-going component vibration assessments, most systems have only isolated concerns with either small exceedances of existing qualification or acceptance testing levels. Some hardware items have yet to be assessed, for example critical connectors for the avionics. The Panel Chair is tracking this information and the status of each system, either for input data they require or assessment work they have yet to complete.

Although the Chair is only formally tasked to produce the acoustic environments, the NESC team finds that this tracking is an appropriate activity necessary for requirement verification for Ares I-X Systems Engineering and Integration (SE&I). It would be best practice if the other environment assessments (e.g. thermal, loads) performed similar tracking of verification completion for SE&I.

The NESC team found concern with the Ares I-X Roll Control System (RoCS), with regard to component vibration assessment, and qualification or acceptance test plans.

As described by MSFC's Mr. Lowery Duvall, the hardware will be requalified since it was not previously qualified to be operational during the high vibration liftoff and ascent regime. This will be "classic" qualification testing whereby qualification units will be used rather than the flight hardware. The NESC team assesses that this will ensure hardware integrity.

As of April 2008, the IPT was not planning to do any vibration acceptance testing on the actual RoCS flight hardware. At the meeting, a representative of the IPT stated that the "USAF didn't accept junk. The USAF had an aging parts mitigation plan, and USAF fired an old rocket (one unit) to show it still worked. So, these combined factors should be sufficient for Ares I-X to accept this hardware as-is."

As of April 2008, the IPT did not have a complete history of the original acceptance testing. It was only clear that some acceptance was part by part and some was lot acceptance. The Teledyne Brown contractor was given an action to find the acceptance test paperwork and assess the old acceptance testing. This was supposed to be completed by mid-May 2008 to support the Critical Design Review-2 (CDR2), which was at the time expected to occur in June 2008, but has subsequently slipped to July 2008.

Further discussions with MSFC Engineering about the approach to VA qualification of the Peacekeeper Missile revealed that the acceptance of hardware occurred as follows:

- All hardware was qualification tested.
- The missile had several flights a year throughout its life time.
- Shelf-stored hardware was accepted and kept operational.
- Old hardware was flown first and new hardware was kept in service or shelved.

The missile was discontinued about 5 years ago and there have been no flights in that time. Accepting the unused hardware is a risk unless records can show that the hardware that was stored, and eventually flown successfully on the missile, was stored for a longer duration than will be the case for similar hardware that will be flown on Ares I-X after having been stored.

Discussions with MSFC also revealed that in some of the missile flights there were anomalies in some of the RoCS components. One example cited was the valves not opening as required. Investigation by Rocketdyne was said to have revealed that the root cause of this was a design deficiency in the valve whereby it required a higher line pressure than was available to open it.

It was also noted that the Peacekeeper RoCS was designed to operate in a vacuum, as would be experienced after the lift-off and atmospheric powered ascent VA environments occur. Therefore, the qualification heritage is useful for evaluating structural integrity, but not for evaluation of RoCS function and performance integrity during ascent, which is the Ares I-X intended use.

6.0 Vibroacoustic Qualification and Acceptance Flowcharts

A recommended decision process flow for considering RoCS VA Qualification is provided in Figure 6.0-1, and a similar decision process for Acceptance is provided in Figure 6.0-2. Tables 6.0-1 and 6.0-2, respectively, provide more detailed commentary for each flowchart block item.

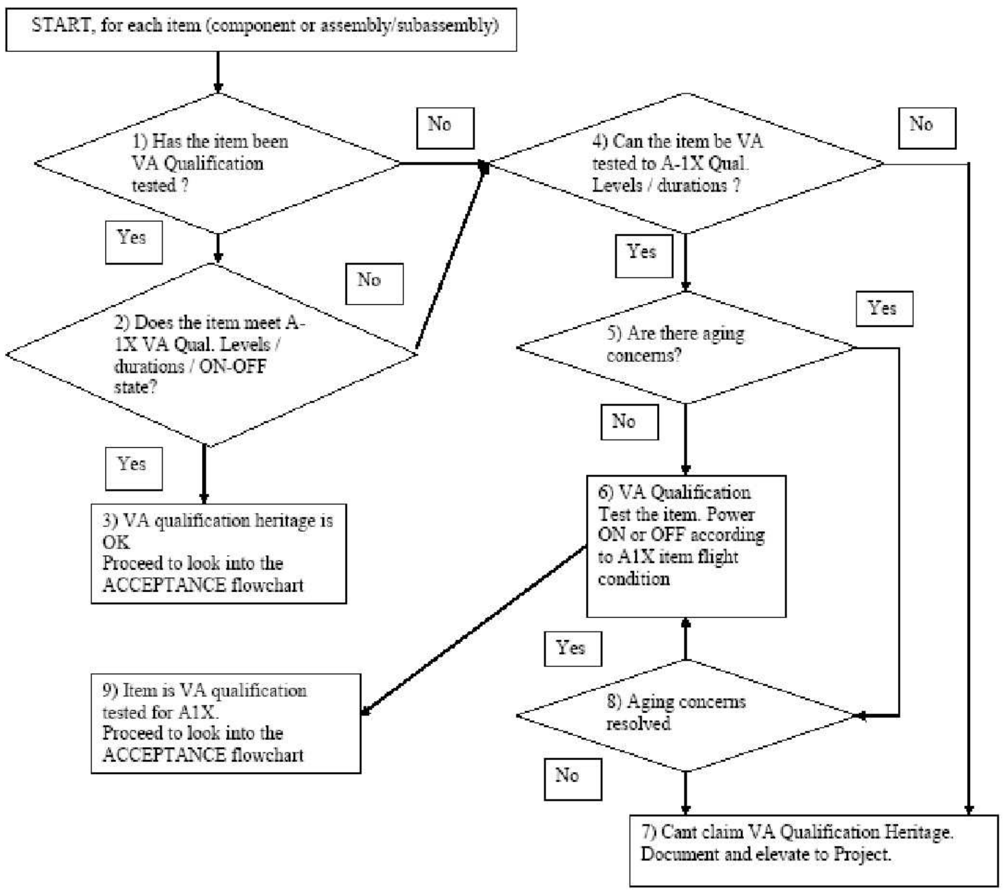

Figure 6.0-1. Vibroacoustic Qualification Flowchart

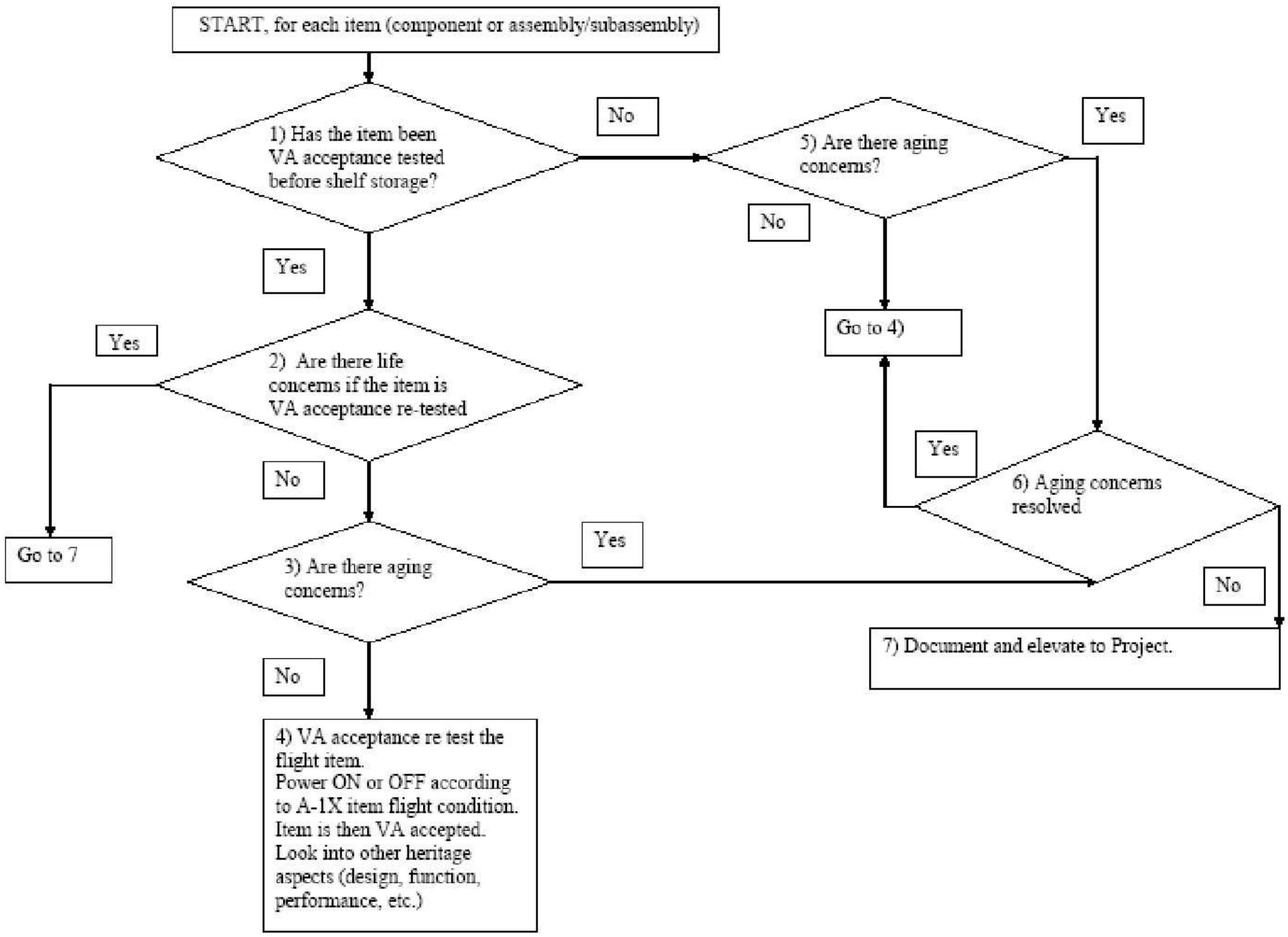

Figure 6.0-2. Vibroacoustic Acceptance Flowchart

Table 6.0-1. Vibroacoustic Qualification Flowchart Description

Block #	Qualification Flowchart Description
1	The data should include the item qualification random vibration test report and/or acoustic test report. Input for test specifications, tolerances, actual input test data, pre- and post-functional and structural integrity checks data is desired.
2	To compare heritage and A-1X qualification specification test magnitudes, durations, axes of exposure and power status during vibration (ON or OFF).
3	The item is declared "VA heritage qualified". Now proceed to the acceptance flowchart.
4	Feasibility to include item configuration, facility capabilities.
5	Related to failure modes that could originate due to aging. For example material creep, seals / joints aging or degradation and stiffness changes.
6	Qualification to the A-1X VA environment (non flight item).
7	Qualification heritage cannot be claimed from the VA perspective. The item VA evaluation has to be elevated to the Project for acceptance under a different justification (waiver) or rejection.
8	For example replacing a seal or a G10 washer.
9	Similar to Block #3.

Table 6.0-2. Vibroacoustic Acceptance Flowchart Description

Block #	Acceptance Flowchart Description
1	The data should include the item acceptance random vibration test report and/or acoustic test report. Input for test specifications, tolerances, actual input test data, pre- and post- functional and structural integrity checks data is desired.
2	If the item is to be re-tested for acceptance or re-work, is there remaining life margin available?
3	Related to failure modes that could originate due to aging. For example material creep, seals / joints aging or degradation and stiffness changes.
4	Actual flight item acceptance re–test.
5	Similar to Block #3.
6	For example replacing a seal or a G10 washer.
7	Acceptance recommendation was not implemented. Project to decide accepting the item with other justification (waiver) or rejection. The proto-flight approach (at the item level or its next level of assembly deferring risk) would still be considered a valid approach to accept the flight item if it has not been heritage-qualified or acceptance-tested before. This is the standard philosophy for Payloads.

7.0 Findings, Observations, and Recommendations

7.1 Findings

The following NESC team findings were made:

F-1. There is not a complete history of tracking for the RoCS of the original Peacekeeper qualification and acceptance testing.

- The IPT is not planning to do any VA acceptance testing on the actual flight hardware.

F-2. There have been reports of flight anomalies in some valves during Peacekeeper test flights. Those were attributed to design.

F-3. The RoCS system does not have formal requirements. Therefore, a verification matrix was not available.

7.2 Observation

The following NESC team observation was made:

O-1. The Vibroacoustics was noted to be functioning more efficiently with improved teamwork and communication since NESC's first participation. This is due in large part to the active participation, inputs and leadership coaching of the Ares I-X SE&I management, and the Aerospace Corporation independent consultant.

7.3 Recommendations

The following NESC team recommendations were made:

R-1. Ares I-X should verify environmental (VA) qualification heritage for all actual flight hardware. This should include verification of whether the components were qualified power ON or OFF during tests. If the heritage qualification levels (durations and power status) are inadequate or non-existent, the hardware should be re-qualified. ***(F-1)***

- Re-qualify the RoCS hardware since it was not previously qualified to be operational during the high vibration liftoff and ascent regime.

R-2. Ares I-X should expand the heritage evaluation beyond the environmental (VA) aspect. This means verify item design requirements, purpose, functionality, performance, reliability, etc. ***(F-2)***

R-3. Ares I-X should perform its own VA acceptance testing for all actual flight hardware (except pyro valves). ***(F-1)***

R-4. Ares I-X should create a Requirements Verification Matrix and keep it up to date for the hardware. ***(F-3)***

R-5. Ares I-X should implement configuration management and traceability for military off-the-shelf items. ***(F-1)***

- This should include keeping tracking records of heritage data (past qualification and acceptance records) and actual testing (qualification and acceptance).

8.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
Finding	A conclusion based on facts established during the assessment/inspection by the investigating authority.
Lessons Learned	Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.
Observation	A significant factor established during this assessment that supports and influences the conclusions reached in the statement of Findings and Recommendations.
Problem	The subject of the independent technical assessment/inspection.
Recommendation	An action identified by the assessment/inspection team to correct a root cause or deficiency identified during the investigation. The recommendations may be used by the responsible C/P/P/O in the preparation of a corrective action plan.

Root Cause	Along a chain of events leading to a mishap or close call, the first causal action or failure to act that could have been controlled systemically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

9.0 List of Acronyms

dB	Decibel
CDR2	Critical Design Review-2
EIDP	End Item Data Package
Hz	Hertz
IPT	Integrated Product Team
JSC	Johnson Space Center
KSC	Kennedy Space Center
MSFC	Marshall Space Flight Center
MTSO	Management Technical Support Office
NASA	National Aeronautics and Space Administration
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
RoCS	Roll Control System
SE&I	Systems Engineering and Integration
USAF	United States Air Force
VA	Vibroacoustic (random and/or acoustic)

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14. ABSTRACT
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